

Synthesis, Structure and Basicity of 1,16-Diaza[6]helicene¹

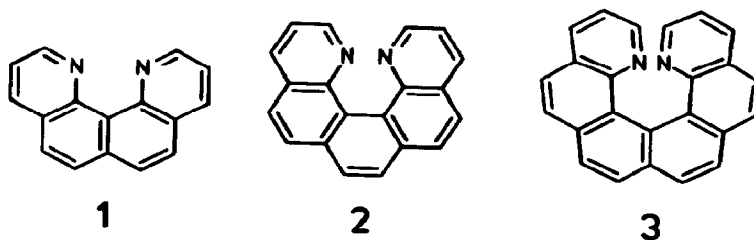
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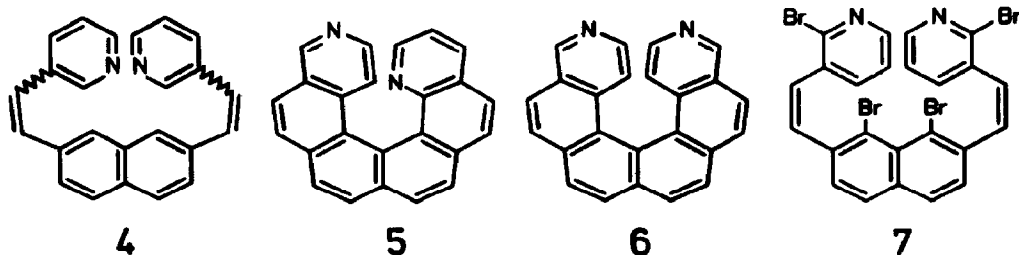
Abstract: The extension of 'proton sponges' **1** and **2** by further anellation to 1,16-diaza[6]helicene (**3**) was of interest to define scope and limitation of 'proton sponge' properties. **3** was prepared by photocyclisation of 2,7-bis(3-pyridylvinyl)naphthalene **4** and by Pd-catalyzed aryl-aryl coupling of the corresponding tetrabromo derivative **7**. As consequence of the helical structure, **3** does not show 'proton sponge' basicity. X-ray structure analyses of **3** and **3·2HBr** are in accordance with these findings.

The high basicity of 'proton sponges'² has been ascribed to the destabilization of the free bases due to repulsive lone-pair interaction of two closely neighboring nitrogen atoms and to the release of this strain on monoproteination leading to a strong N...H...N hydrogen bond. In agreement with this explanation, a systematic variation of the spatial arrangements of the two basic nitrogen centres proved the N...N distance in the free bases and the degree of linearity of the N...H...N hydrogen bond in the monoprotinated species to be essential factors for the basicity³.

The original 'proton sponges' were of the general type of bis(dialkylamino)arenes which due to the hydrophobic shielding of the basic centres represent kinetically rather inactive bases. With the synthesis of quino[7,8-*h*]quinoline (**1**)⁴ a first member of a new type of 'proton sponges' was obtained combining high basicity with a fast proton-exchange rate which is required for applications as auxiliary bases in base-catalyzed reactions. As expected, the corresponding 1,14-diaza[5]helicene (**2**)⁵ is also a kinetically active base; transprotonation experiments with 1,8-bis(dimethylamino)naphthalene³ showed, however, that the basicity of **2** is about two powers of ten smaller than the basicity of **1** although the N...N distance in **2** is shorter than in **1**. In fact, the X-ray analysis proved for **2**, in contrast to the planarity of **1**⁶, a helical structure by which the destabilizing lone-pair interaction in the free base is reduced, and a linear N...H...N hydrogen bond along the favored direction of the nitrogen lone-pairs is no longer possible on protonation. If this interpretation is correct, these effects should be much more pronounced for 1,16-diaza[6]helicene (**3**) on the synthesis, structure and basicity of which we report in this communication.



With the intention to synthesize **3**, the diylide of 2,7-bis(triphenylphosphoniomethyl)naphthalene dibromide⁷ (sodium bis(trimethylsilyl)amide, THF) was reacted in a double Wittig reaction with pyridine-3-carbaldehyde (THF, 3 h, -78 °C; then 12 h at 20 °C) to yield 2,7-bis[2-(3-pyridyl)vinyl]naphthalene (**4**) as isomer mixture (*EE/EZ/ZZ* ≈ 29:55:16; total yield 88%). By photocyclodehydrogenation in analogy to ref.⁸ (iodine, propylene oxide, benzene/methanol, 6:1; irradiation by Hg-hp-lamp, 24 h, 20 °C) **3** was obtained in only 1.7% yield (m. p. 257 °C)⁹. **3** and its isomers 1,14-diaza[6]helicene (**5**, m. p. 227-228 °C); yield 25%)⁹ and 3,14-diaza[6]helicene (**6**, m. p. 318-320 °C; yield 11%)⁹ were separated by chromatography (silica gel, trichloromethane/ethyl acetate/ethanol, 5:5:1) and further purified by preparative layer chromatography and crystallization; the assignments are based on ¹H-NMR.



The unsatisfactory yield obtained for **3** stimulated various attempts to synthesize **3** in reactions of higher regioselectivity. Of these experiments¹⁰ the palladium-catalyzed intramolecular cyclization of 1,8-dibromo-2,7-bis[2-(2-bromo-3-pyridyl)vinyl]naphthalene (**7**), a tetrabromosubstituted analogue of **4**, proved to be successful. **7** was obtained by double Wittig reaction of 2-bromopyridine-3-carbaldehyde (from 2-bromopyridine by lithiation and subsequent formylation, 42% yield; m. p. 72 °C)⁹ with 1,8-dibromo-2,7-bis(triphenylphosphoniomethyl)naphthalene dibromide⁹. The latter was prepared in five steps either from 1-bromo-2,7-dimethylnaphthalene¹¹ or from 1-nitro-2,7-dimethylnaphthalene¹². The intramolecular coupling of **7** to **3** was achieved in analogy to ref.¹³ by reaction with tetrakis(triphenylphosphine)palladium and hexamethyldistannane in dry toluene (95 h heating under reflux). Working up by filtration, washing of the organic phase with water, drying and distilling off the toluene left **3**: after chromatography (see above) and crystallization from ethyl acetate pure yellow prisms were obtained (m. p. 257-258 °C; 52% yield), in all spectroscopic properties identical with **3** prepared from **4**.

The molecular structure of **3**¹⁴ is shown in Figure 1A in a view perpendicular to the mean ring plane of the central 'naphthalene' part of **3**, in Figure 1B in a projection along the C₂-axis of the molecule which demonstrates the strong helical deformation which is similar to the structure of hexahelicene¹⁵. The distance between the two nitrogen atoms in 1- and 16-positions with 279.1 pm is in the same order of magnitude as in typical proton sponges^{3,6}; these distances, however, are not strictly comparable because in **3** the N...N-distance is measured nearly perpendicular to the planes defined by the covalent bonds on the two nitrogen atoms.

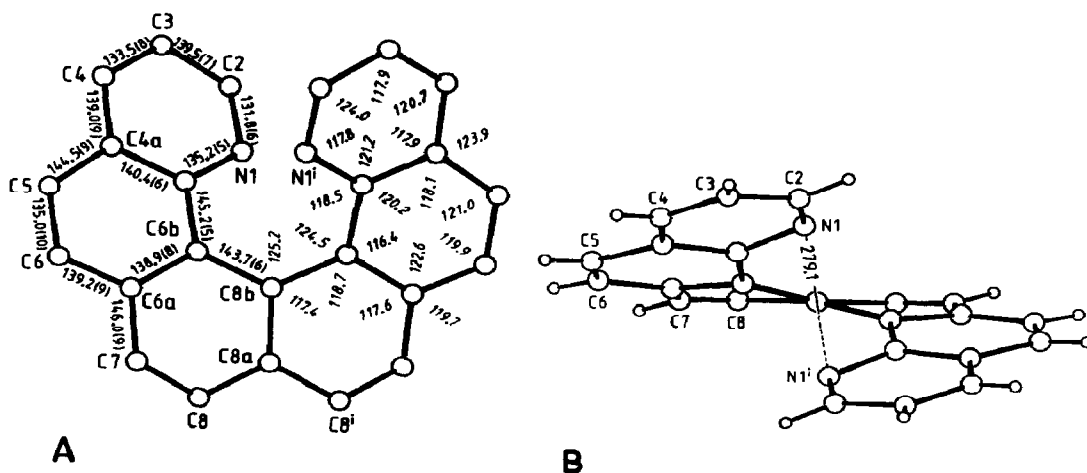


Fig. 1 Molecular structure of **3**, in a view perpendicular to the mean plane of the central 'naphthalene' part (A) and in a side-view along the C_2 -axis of the molecule (B).

Whereas for typical 'proton sponges' even with excess of very strong acids only monoprotonation is observed, **3** with gaseous hydrogen bromide in ethyl acetate yielded easily the diprotonated species **3·2HBr** (yellow crystals, dec. > 300 °C)⁹ which by crystallization from methanol formed crystals suitable for X-ray analysis¹⁴. The molecular structure (Figure 2) shows the diprotonation on N(1) and N(16) leading to two pyridinium-like units. The helical deformation is stronger than in neutral **3** leading to an increased N...N-distance of 291.1 pm.

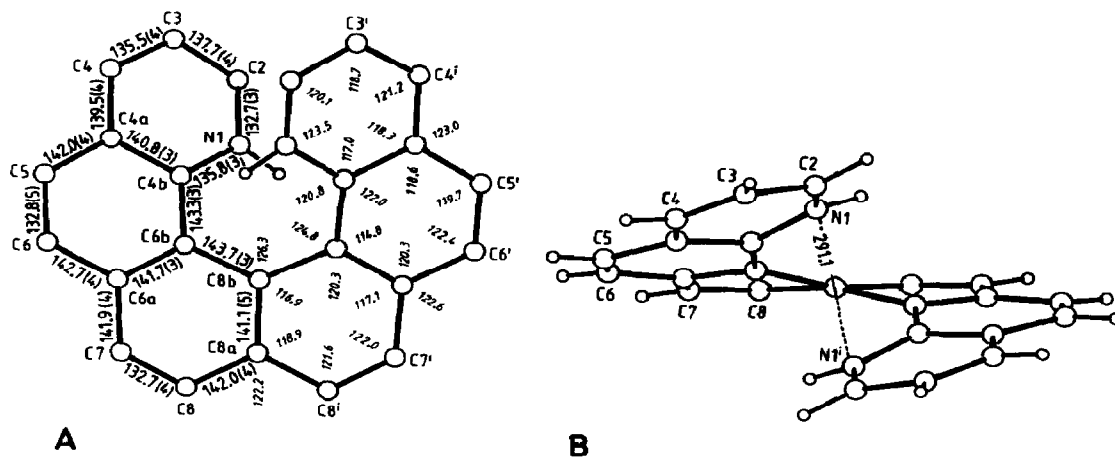


Fig. 2. Molecular structure of **3·2HBr**, in a view perpendicular to the mean plane of the central 'naphthalene' part (A) and in a side-view along the C_2 -axis of the molecule (B).

Preliminary experiments to determine the basicity of **3** by $^1\text{H-NMR}$ measurements of transprotonation reactions of **3** in DMSO with bases of known pK show that the basicity of **3** is in the order of that of pyridine ($pK_{\text{DMSO}} \approx 3.5$). - In a separate paper¹⁶ mass spectrometrical investigations of **3** and its isomers **5** and **6** are dealt with which demonstrate unique fragmentations depending specifically on the aza-positions and on the helical structure of these compounds.

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14. Crystal structure analysis of **3**: orthorhombic crystals (from diethylether); crystal size 0.2-0.2-0.4 mm; space group *Fdd2* (no. 43 Int. Tables), $a = 1108.1(1)$, $b = 2993.9(2)$, $c = 982.6(2)$ pm; $Z = 8$, $D_{\text{calc}} = 1.346 \text{ g}\cdot\text{cm}^{-3}$; 1041 reflections to $\sin \theta/\lambda \leq 6.6 \text{ nm}^{-1}$; 772 reflections with $I \geq 3.00 \sigma(I)$; structure solution by direct method (MULTAN), $R = 0.067$. - Crystal structure analysis of **3-2HBr**: monoclinic crystals (from methanol); crystal size 0.1-0.1-0.3 mm; space group *C2/c* (no. 15 Int. Tables); $a = 1242.6(2)$, $b = 1221.5(2)$, $c = 1312.1(2)$, $\beta = 100.68(2)^\circ$; $Z = 4$, $D_{\text{calc}} = 1.671 \text{ g}\cdot\text{cm}^{-3}$; 1913 reflections to $\sin \theta/\lambda \leq 6.2 \text{ nm}^{-1}$; 1509 reflections with $I \geq 3.0 \sigma(I)$; structure solution by heavy-atom method (PATTERSON), $R = 0.025$. - Further details of the crystal structure analyses are available on request from the Cambridge Crystallographic Data Centre by quoting the name of the authors and the journal citation.
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